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the self-judgement principle in chemical data processing

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When two chemical species, each of which is capable of independent existence, are dissolved in an inert solvent, it frequently happens that some sort of association between the two different types of dissolved molecules occurs. The resulting "complexes" have been studied for many years, and are of great importance in many phases of chemistry. An example of one type of complex is the deep blue $Cu(NH_3)_4 + 2$ ion which should be familiar to all who have been exposed to elementary chemistry courses. In this species, nitrogen atoms are held to the Cu atom by strong chemical bonds, of a type which is now quite well understood.

By no means do all complexes have this relatively simple type of bonding. In an important class of complex species, the constituent particles are held together by bonds which are weaker than ordinary chemical bonds. A widely accepted theory proposed by Professor Robert S. Mulliken, of the University of Chicago, ascribes the bonding in these "charge transfer complexes" to forces arising from interactions of the excited states of the constituent molecules.

The nature of the bonding in these systems is such that even rather weak interactions with a solvent cause significant effects on the stability of the complex species. According to Prof. P. D. DeMaine of the University of Mississippi, an AFOSR grantee, significant factors can be either completely missed or misunderstood if apparently minor effects are not given proper consideration. Experimentally observable phenomena which are of very high significance occur close to the limits of error imposed by the instrumentation used in the measurements.

In former studies, systematic experimental errors have been considered in a relatively cursory fashion. DeMaine feels that rigorous treatment of instrumental errors makes possible

accurate study of higher-order effects which are of great importance in achieving understanding of these complexes and their properties. In order to facilitate consideration of these relatively complicated instrumental factors, a number of special computer programs have been devised. These allow the use of predetermined instrument error factors and raw data to compute parameters with precisely known ranges of error. The DeMaine group is extremely productive, having developed novel aspects of computer science and applied these to many important chemical systems.

As an example of the use of these techniques, we may note the recently completed spectrophotometric investigations of the s-trinitrobenzene-naphthalene complex in six nonreactive solvents. DeMaine interprets his computer-processed data in terms of several isomeric forms of the complex and states that his results disprove previously held notions involving relatively imprecise concepts such as "activity effects" or "nonspecific solvent effects." The last statement is, to say the least, provocative of further work. Controversy and progress in this field aid understanding in areas of critical importance such as energy transfer in fluid and solid systems.

lunar TRANSPONDER

MAHLON S. HUNT, *Terrestrial Sciences Laboratory*, AFCRL

A prototype lunar transponder-- a device for receiving and retransmitting a radio signal-- has been developed for AFCRL. This device, if placed on the visible face of the moon and tracked from the earth, will provide scientists with another way to measure earth-moon distances.

The transponder is designed to withstand a shock of 3000 G's in any direction for a duration of three milliseconds. It weighs a mere 4.3 pounds, excluding batteries, and has a volume of about 90 cubic inches.

Similar to a frequency-modulation transceiver, the transponder receives a frequency-modulated 5052 Mcps carrier signal and simultaneously retransmits the signal on the same antenna on a 5000 Mcps carrier. Radio signals make the round trip to the moon in about 2.5 seconds.

The transponder was originally designed to meet general lunar hard-landing requirements; but its light weight and ruggedness make it adaptable for use in other lunar vehicles. Such a device could also be used as a navigational beacon. If sufficient observational data is acquired from such a lunar transponder, knowledge pertaining to the lunar orbit, the solar parallax, and the moon's librations could be independently confirmed, tested and extended.

The prototype transponder was developed by General Dynamics/ Astronautics, under AFCRL contract. It represents one basic-research study directed towards the extension of terrestrial geodesy into aerospace.

ANATOMY of the BRAIN | 3 STUDIES

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No physical mechanism defies understanding more than that which gives rise to human mental processes. A satisfactory model -- or description -- of these processes in terms of the known componentry of the brain has eluded all those who have considered the matter. We can describe this componentry quite readily. We know that the human brain consists of some 10 billion cells, and we know much of the pattern of dendrites and axons branching out from these nerve cells. We know that, throughout a person's life, he loses some 10 thousand nerve cells each day and that they are not replaced. Further, we know something of the brain's gross electrical characteristics, and of the parts of the brain which govern certain mental activities. Lastly, microbiologists are on the threshold of understanding something of the chemical changes -- such as changes in ribonucleic acid (RNA) -- brought about in the brain by learning processes.

But we do not know how the brain responds to inputs from the external environment, how it takes these inputs to form associations among related and disparate data, how it analyzes and recognizes patterns, how it catalogs and stores information, how it retrieves facts unused for many years from some inner recess, and how it administers and programs its own activity.

Many studies have been undertaken to explain certain aspects of this activity. Three AFCRL efforts related to neural functions are reviewed in the following paragraphs.

In September 1963, a special computer was delivered to AFCRL's biophysics group. This computer processes on a real-time basis the data from as many as eight microelectrodes implanted in the brains of animals. The purpose of this work is to trace patterns of electrical activity in the brain. We want to see what happens when we stimulate certain of the animal's senses. Does a particular neuron in a particular location "fire?" Does the "firing" trigger the firing of neighboring neurons? What is the rate of propagation of the chain of firings? In what directions do the firings propagate?

This new computer--known as the LINC computer--was jointly designed by Lt Charles E. Molnar of AFCRL and by a group under Wes Clark at Lincoln Laboratory. With it, AFCRL's biophysics program enters a new phase.

In another approach to the study of neural behavior, Dr. Edmond Dewan of AFCRL sees the electrical output of the brain as analogous to linked nonlinear oscillators. His study is concerned only with gross electrical behavior. Some results of Dewan's study were presented in a prize-winning paper at the recent 10th Annual Air Force Science and Engineering Symposium held at Colorado Springs, Colorado, 8-10 October 1963.

Dewan uses his linked nonlinear oscillator model to explain certain mental aberrations, such as epilepsy. Sometimes--by spontaneous action or by induction through external stimuli such as a rapidly flashing light--these oscillators can be locked in phase. When this happens, epilepsy or unconsciousness results. This study has led Dewan to a proposed technique for using thought processes to operate switches. Equipments to evaluate this technique have been ordered. When these investigations get under way, they will be described in detail at a later time.

The third study focuses on just one of the brain's functions--processing visual data. How the brain copes with the rich multiplicity of things in our visual world--the fine textures, the infinite colorations, the movements, the dimensions of things and their spacial relationships--all remains an enigma. We can only suggest in a limited way how the brain might begin to bring order to the data.

As a first step toward an understanding, we must take into account known physical and psychological aspects of vision. Thus we are immediately faced with constraints. In taking into account these known constraints, Harry Blum, who is investigating aspects of visual data processing at AFCRL, departs sharply from others working in the broad area of pattern recognition. Most pattern-recognition schemes are oriented around existing electronic data-processing techniques. Blum's work has led him to a model which starts with the processing of two-dimensional geometric patterns. But, from the processing of two-dimensional patterns in space, a three-dimensional space can be assembled.

The model borrows some known properties of neural activity, but does not purport to replicate these activities. As its first step, it translates the original visual pattern into a second pattern which better lends itself to processing techniques. But the second pattern alone has little value. How this pattern is created in time must be known. The "time" aspect gives an essential mathematical function to work with. The translated pattern is usually a simple line abstraction which may bear no correspondence in appearance to the original image.

The "drawing" of an abstracted line may be initiated at two or more locations. It is "traced" at varying rates of speed depending on the original image. The rate may be linear, exponential, or grossly

irregular. But, when the resulting trace and its time-history are known, it is possible to reconstruct all aspects of the original pattern--its jaggedness, its bulbousness, its connectedness, and so on.

How do we derive this abstraction? The outline of the original pattern must be thought of as a radiator propagating evenly in all directions. For all possible shapes in the visual field (with the exception of a single point or a straight line), the expanding outward or inward radiation from two or more points along the pattern will converge--or meet. The abstracted image is drawn in time along the line of convergence. The radiating energy cancels itself on convergence.

Let's look at several simple patterns and see how this works. If we start with an ellipse, the resulting pattern, based on this radiator scheme, will be a straight line--but a line which begins at two locations near each end of the ellipse and works its way to the center. In the case of a square, the resulting pattern would be an X--the trace of which would begin at each of the four corners, with the four spokes of the X moving inward toward the center. The outline of a man would give the familiar stick figure that a child draws.

With this translation process as the basis of the over-all model, Blum shows that it is possible to derive a memory and association mechanism. The mathematics, the geometry and the important time-sequencing involved are all described in several papers and reports prepared by Blum. Here, only gross aspects are considered.

The process operates in two stages. The first stage (designated the input plane) takes the external pattern and transforms it into the abstracted pattern. The abstracted pattern is then transferred in time to the second processing stage which may be conceived as a volume of transponders. Each transponder receives a signal and each can--if the signal meets certain criteria established within the transponder--rebroadcast it from transponder to transponder throughout the transponder volume. The transponders serve as memory elements; we conceive each as having a matched filter circuit which permits the transponder to relay the signal when the incoming signal matches its filter.

The study, which has now been in progress for some time, has reached the stage where Blum is considering equipments for implementing the model. An input plane is now being built. This input plane will be used with a conventional computer for preliminary investigation of the over-all model.

* * * * *

*Hitherto a man has been living in a slum, amidst quarrels, revenges, vanities, shames and taints, hot desires and urgent appetites. He has scarcely tasted sweet air yet, and the great freedoms of the world that science has enlarged for him....***H. G. Wells**

conduction errors in aerodynamic heat-transfer measurements

1st Lt WILLIAM G. REINECKE, *Hypersonic Research Laboratory*, ARL

The Air Force is vitally interested in the heating problems involved in atmospheric re-entry and sustained hypersonic flight. This interest is reflected in the in-house research effort of the Hypersonic Research Laboratory of ARL where the author, in conjunction with Mr. A. R. George of the Aeronautical Engineering Department of Princeton University, has recently published an analysis of one of the experimental errors which arise in the so-called thin-skinned method of measuring aerodynamic heating rates (see reference). This method is one of the most common ways of determining supersonic and hypersonic convective heating rates.

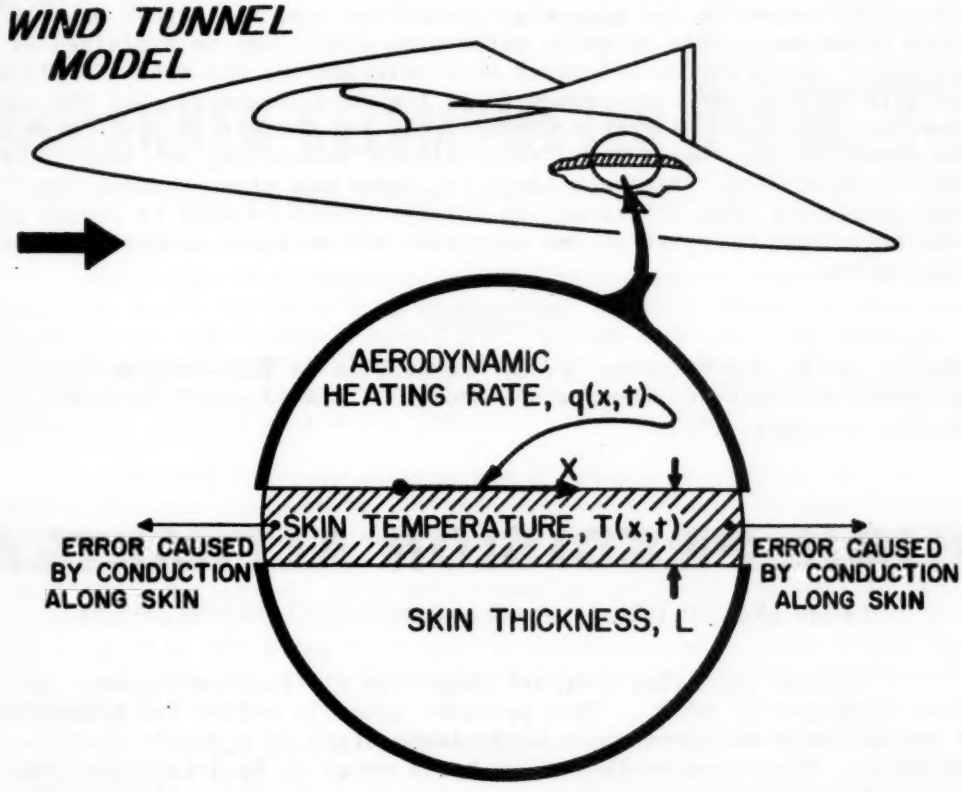
The thin-skinned method uses a hollow model with a thin, usually metal skin (see figure). At the start of an experiment, the model is at a steady, uniform temperature. The gas flow over the model then is established quickly (for example, by injecting the model into the gas stream), and the time variation of the skin temperature is recorded at different positions on the model. The experimenter commonly considers the temperature of the skin to be constant in the direction normal to the skin surface. In addition, he assumes that there is no conduction along the skin or to the interior of the model. Then a simple calorimetric heat balance for an element of model skin yields the equation

$$q = DCL \frac{T}{t},$$

where q is the convective heating rate per unit area, D, C, and L are the density, specific heat, and thickness, respectively, of the skin, and T/t is the partial derivative of skin temperature with respect to time. However, as the model begins to heat, the surface temperature

will become nonuniform. This will, in turn, lead to conduction along the model skin and introduce an error into the above simple equation.

The analysis in the reference results in a formula which allows the experimenter to estimate the error in the measured value of q (shortly after the test is started) caused by the conduction along the skin. The analysis allows for any model geometry and for variable skin thickness and recovery temperature. As a simple example, let us consider a section of the model wing which is of uniform thickness and is being



heated uniformly along its span. In this simplified case, the percentage error induced in the measured value of q is given by

$$\frac{100}{q}\,\frac{k}{DC}\,\frac{{}^{2}q}{x^{2}}$$

where k is the conductivity of the skin and x is the chordwise distance along the wing. (The detailed restrictions on this formula are given in the reference.) To use the results, the investigator either makes an a priori calculation of q (x,t) or uses his measured values. If the measured values of q are used, and the calculated error turns out to be small, then the measurements are accurate.

In addition to allowing the investigator to estimate the conduction error in his experiment, two conclusions can be drawn from the error expression. First, the heating rate should be measured as soon as possible after the start of the heating (when t is taken to be zero) allowing, of course, a very short time for the temperature to become uniform in the direction normal to the skin surface, as assumed. This conclusion is intuitively fairly clear and means, in practice, that the gas flow over the model must be established quickly and that the skin temperature should be measured with fast time response instruments. The second conclusion, which may not be so clear, is that the percentage error caused by the chordwise conduction does not depend on the skin thickness. This slightly surprising result may be explained as follows: since the skin behaves as a calorimeter, the nonuniformities in skin temperature vary inversely as the skin thickness; but the conduction rate itself is proportional to L, and the effects just cancel. In practice, this means that "thin-skinned" models may not have to be very thin-skinned. Although there are sometimes other reasons for desiring small skin thickness, no attempt should be made to reduce conduction errors by constructing expensive and delicate models with very thin skins.

REFERENCE

George, A. R. and Reinecke, W. G. "Conduction in Thin-Skinned Heat Transfer and Recovery Temperature Models." AIAA Journal, Volume 1, Number 8, August 1963.

HIGH-PRECISION ALTIMETER

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A novel precision pressure gauge for altitude measurement has been developed by AFCRL. This pressure gauge is called the hypsometer, a device which measures the boiling temperature of a liquid (butyl-benzene). The corresponding atmospheric pressure is determined from the known boiling-temperature-versus-pressure characteristic of the liquid. This liquid is electrically heated to its boiling point and kept at that point for the duration of flight, often for periods of from two to three weeks. Accuracy calls for chemical purity of the liquid, the ability of the associated internal circuitry to maintain the butyl-benzene at its boiling point, and the accuracy of sensing this temperature.

At the higher altitudes, the hypsometer provides a great improvement in precise altitude measurement. For example, at 120,000 feet or 4.71 mb pressure, the altitude error is only about one tenth that of previous altimeter devices -- 240 feet as against 2,600 feet.

Several hypsometers were simultaneously tested for repeatability through a series of balloon flights earlier this year. In the final flight of the series, with measurements made at a float altitude of 120,000 feet, three hypsometers gave an average pressure-altitude deviation of 182 feet from the mid-value. These hypsometers will be used on all future balloon high-altitude research flights where precise and reliable altitude determination is a necessity.

The hypsometer was developed at AFCRL under the direction of Dr. W. C. Wagner.

UNMANNED SEISMOMETER NET

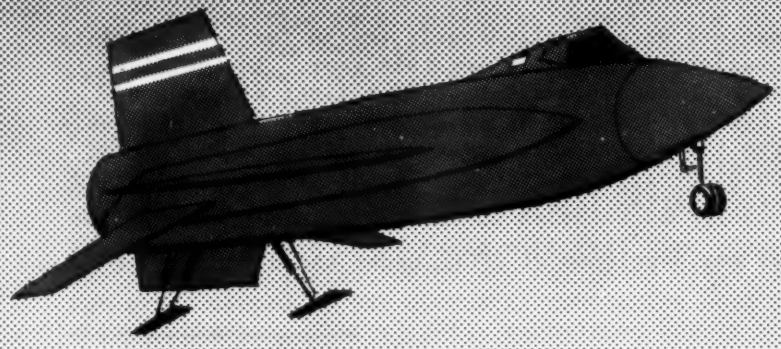
HENRY A. OSSING, *Terrestrial Sciences Laboratory*, AFCRL

Detection of underground nuclear explosions by means of seismometers is quite feasible technically. But when you begin to apply the technique to some reliable operational scheme, you run into problems. One outstanding difficulty has recently been overcome at AFCRL. This has to do with the remote transmission of seismic data from unmanned sites to a central monitoring station.

AFCRL has recently established a seismic network of four unmanned stations equipped to transmit data over special telephone lines to visual and tape-recording devices at a central location. The unmanned sites are located at Caribou, Machias, and Milo, Maine, and at Berlin, New Hampshire. Data from these stations are transmitted to the Weston Observatory in Massachusetts. The furthermost station in the network is 356 miles from the Weston Observatory. This marks the first time that seismic information has been successfully transmitted over long distances.

The network will be used to study methods for overcoming the largest single problem involved in the detection of underground explosions--that of separating signals of interest from similar signals generated by quarry explosions, sonic booms, train and highway noise, ocean surf, and of course natural earthquakes. All create similar squiggles on a seismograph. Earthquakes make up the greater portion of the recorded events. An annual average of about 12,500 severe-to-moderately severe events are recorded. The highest proportion of these occurrences take place in so-called seismic areas--the Aegean region, along the west coast of North and South America, Japan, and so on.

The AFCRL network in New England is located in a relatively quiet seismic area, and will be used to make comparisons with recorded events in the active regions of the world.



shoe boxes are for shoes

Dr. HAROLD WOOSTER
Directorate of Information Sciences, AFOSR

Like the pilot of a ski-wheel aircraft, one of the recurring problems of the information-system designer is whether to use the wheel or the sled runner. Both are reinvented in recurring cycles--the landing skids of the X-15 are as brilliant a design solution as were the runners of the original Wright biplane.

The ski-wheel dilemma of the information-system designer is found in many forms. One of these occurs when he attempts to provide the individual user of the system with his own reference collection of items. These may be abstracts, or regulations, or sheets giving the properties of chemical compounds, or individual research-effort descriptions, as on DD 613's, or catalog cards. The nature of the item does not matter; what does matter is that, to be used effectively, these individual items must be filed in some sort of logical order.

There are at least two possible approaches. One is to prefile by binding the items together in a book. The other, and superficially more attractive approach, is to issue the items as individual pieces of paper with detailed instructions as to where they should be filed, and count on the user (or more realistically, his secretary) to put the separate pieces of paper in the correct places in a three-ring binder or card file.

All too frequently, the designer who has chosen this alternative finds that he has invented one more shoe-box information system--a shoe-box information system being defined as a shoe box full of cards that the user is going to get around to filing some day.

There are valid arguments in favor of both forms of dissemination--the convenience of the book, say, as contrasted to the currency of a

properly maintained file of separate items. Detailed cost-effectivness studies on the two approaches have been lacking until a recent AFOSR-sponsored study by Dr. Fred Heinritz of the Graduate School of Library Service, Rutgers University, published in Library Resources and Technical Services, Vol. 7, pp 229-236 (1963).

Dr. Heinritz (this study was part of his doctoral dissertation) was able to secure the cooperation of Engineering Index, Inc., which produces both sets of 3" x 5" index cards and monthly and annual volumes in making a detailed study of their production and distribution methods and costs. The cards are typed (on a Justowriter), photoreduced onto a Multilith offset master, Multilithed, slit and distributed as cards; the proof copies of the cards are saved, assembled and photographed for printing as the monthly and annual volumes.

Holding as many variables constant as possible (e.g., since the cards do not have an author index while the magazine does, the cost of the author index was eliminated from that of the magazine), and leaning over backwards in favor of cards whenever possible (e.g., providing for the costs of two sets of volumes to each set of cards to allow equal access time since, even in the New York Public Library at its busiest, less than 4 per cent of the catalog drawers are in use at any one time), Dr. Henritz made his calculations. He set up the following table of relative annual production, distribution and use costs (excluding searching costs) of a comparable card and magazine service, each producing 988 sets of 36,500 entries each, and distributing them monthly.

	Magazine	Cards
Production	$170,026.75	$211,464.22
Distribution	2,267.31	55,404.52
Subscriber use (excluding searching cost)		
Filing	---	$346,096.40
Equipment for use	381.26	65,563.60
Space for use	3,609.00	114,777.00
Subscriber use total	$ 3,990.26	$526,437.00
GRAND TOTAL	$176,840.53	$793,305.74
Cost per set	178.99	802.94

Admittedly, it may well take less time to search for information in a properly maintained card catalog than it does in a book. In one experiment, it took 113 minutes to look up 100 items in a card catalog; looking through a comparable book took 133 minutes for the same number

of items. A card catalog in heavy use may well be worth the trouble of establishing and maintaining it.

This is not the problem posed initially, however. Cards on separate pieces of paper cost about 1.5 times as much to produce and distribute as the same cards assembled in a book. This difference in production costs could be tolerated if it were compensated for by a corresponding reduction in cost to the user. The contrary is the case. A card system costs the user some 100 times as much to file and store as the same information in books!

Modern printing methods do make it possible to issue inexpensive, disposable book-form publications instead of lots of separate pieces of paper. (The mind boggles at the thought of a telephone directory issued on 3" x 5" cards with change orders.) Unfortunately, it is all too easy to focus just on printing costs and ignore the total costs of an information system. Concern with reducing the cost of information-dissemination systems must be concentrated on reducing the cost of the total system and not merely the costs of production and distribution.

A TEST
for the test-tube synthesis of enzyme protein

Captain B. D. STOLLAR, USAF (MC), *Biological Sciences Division*, AFOSR

An army of molecular biologists is converging on the problem of synthesizing complex protein in a controlled system free of intact living cells. As has been described previously in these reviews, the general features of the translation of genetic information into the synthesis of protein have been learned. In brief, deoxyribonucleic acid (DNA) contains a four-letter code which is translated into a complementary four-letter code in ribonucleic acid (RNA); this substance then serves as a template directing the sequences of twenty types of amino-acid units which are built into proteins.

How far have we progressed in the attempt to reconstruct these processes by recombining isolated defined chemical substances? DNA can be isolated in a highly purified form of high molecular weight. An enzyme which can lead to the synthesis of new DNA from the nucleotide building block components has been isolated. Another enzyme which has been isolated can build RNA complementary to the DNA chain, in a cell-free reaction mixture. It requires the DNA as a template, magne-

sium ions, the four nucleotide units which will make up the RNA, and a known energy-rich compound.

The next step is to translate this new RNA into a chain of amino acids. In 1961, a test-tube system recombining several cell fractions was found capable of doing this job. Many types of polyamino acid chains have been built with this system, though only certain model polymeric products have been fully characterized. Analysis of the still complex components of the system has led to the isolation of several enzymes and other required factors. The great step remains of actually building a recognizable protein with characteristic activity, such as enzymatic catalysis.

In the attempt to accomplish this feat, some workers have prepared the RNA template and ribosomes (particles on which proteins are built in living cells) from bacterial cells which were just beginning to synthesize a known specific enzyme. The RNA template and ribosomes were added to the test-tube system prepared for synthesis of polyamino acid chains, in the hope that this template would direct the synthesis of a specific enzyme in the cell-free system. Also added were the monomeric amino-acid units, bearing a radioactive label in the form of C^{14}. An increase in the specific enzyme activity was observed as the reaction mixture was incubated; at the same time, amino acids were taken up into a polymeric form. This uptake was detected by the appearance of the radioactive label in the polymers. Can it be concluded from these two observations that the uptake of amino acids was involved in the synthesis of brand-new enzyme molecules in this cell-free reaction, or was the increase in enzyme activity due to preformed or nearly finished protein being released from the ribosomal particles? Not all scientists have agreed on the answer to this question; but Dr. H. O. Halvorson of the University of Wisconsin, an AFOSR grantee, has adapted a useful technique to put the question to a test.

For this test, one incubates the same basic components as mentioned above. Instead of using radioactive amino acids, however, Halvorson suggested the use of amino acids containing the heavy isotopes N^{15}, C^{13}, or deuterium to replace the normal nitrogen, carbon or hydrogen. Any new proteins built with these amino acids by the test-tube systems will thus be heavier than normal proteins, and their density in solution will be greater. This change in density can be detected by a technique known as gradient-density ultracentrifugation, which has been of great use previously in the study of nucleic acids.

For this technique, one prepares a concentrated salt solution, such as rubidium chloride. When a centrifuge tube containing this solution is rotated in an ultracentrifuge, the solution becomes distributed throughout the tube in such a way that the portion farthest from the axis of rotation has a higher density than the portion nearest the axis of rotation, and a gradient of density forms between the two ex-

tremes. One can choose a salt solution of concentration such that normal proteins will have a density, in solution, corresponding to an intermediate point in the rubidium-chloride density gradient. During ultracentrifugation, the protein will accumulate in a relatively sharp band at that point where its density equals that of the salt solution. Any protein containing heavy isotopes will have a greater density and will form a band farther from the axis of rotation, and separate from the normal proteins.

Halvorson has shown that it is in fact possible to separate normal proteins from heavy-labeled proteins (made separately by intact cells grown in the presence of heavy amino acids) in just this way. With careful handling, one can then take the tube from the ultracentrifuge, puncture a minute hole in its bottom, and collect drops into fractions corresponding to different levels in the tube. The heavy protein can be collected separately from the normal ones.

How can this method be applied to the question of whether the test-tube system described above was building a completely new active enzyme? After a period of incubation of the reaction mixture with heavy amino acids, the products may be analyzed by the density-gradient technique. Success in building a new enzyme protein should be indicated by a new, denser protein band in the centrifugation pattern, and the material in this band should have specific enzyme activity.

To date, this result has not been achieved. While increased enzyme activity was observed in Dr. Halvorson's experiment, the new band was not seen. The heavy amino acids must have been taken up randomly into all growing chains with no formation of completely new chains consisting only of the heavy amino acids. The increase in enzyme activity must have been due to the finishing or release of nearly completed chains preformed on the ribosomes.

The analysis of individual components is continuing. A great deal of progress in this analysis was reported at the recent Cold Spring Harbor Symposium in Quantitative Biology, held at Cold Spring Harbor, Long Island, 7-13 June 1963, and supported in part by AFOSR. It is probable that, in the foreseeable future, it will be possible to build a recognizable protein in cell-free preparations. When the right combination is found, Halvorson's adaptation of the gradient-density centrifugation method of analysis will provide a test of true success.

* * * * *

He who advertises his name, loses it; he who does not increase (knowledge) diminishes it; he who refuses to learn, merits extinction; and he who puts his talent to selfish use, commits spiritual suicide.... **Talmud**

to our readers

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